Title: Strategic Tillage to Improve Crop Yields and Profitability in Dryland No-Tillage Cropping Systems

Principal Investigator: Augustine Obour (Soil Scientist, KSU Ag Research Center-Hays),
Co-PIs: John Holman (Cropping Systems Agronomist, KSU Southwest Research and Extension Center, Garden City), and Alan Schlegel (Soil Management, KSU Southwest Research and Extension Center, Tribune).

Summary
Adoption of no-tillage (NT) systems has several benefits to dryland crop production in the central Great Plains (CGP). These include improving soil properties, reduced wind erosion, save energy inputs, increased retention of soil moisture, and improved yields. Despite these benefits, continuous NT tends to cause stratification of soil nutrients and pH, soil compaction, lack of effective control of some grass weeds and most recently, emergence of herbicide resistant weeds. Strategic tillage operations timed when soil erosion risk is low on an otherwise NT field could break up stratification of soil properties, reduce noxious weed populations and improve crop yields. This has the tendency to increase the productivity and profitability of dryland cropping systems in the region. There is limited information on the impact of occasional tillage on soils that have been in long-term (> 40-yr) dryland NT wheat-based cropping system. This proposed project will determine crop production and soil quality attributes as affected by tillage of long-term continuous NT experimental plots in western Kansas. Crop yields, soil water storage, changes in soil organic carbon (SOC) and carbon dioxide (CO_2) emissions will be compared among continuous NT and a one-time tillage of long-term NT plots in wheat-sorghum crop rotation systems. In addition, the impact of occasional tillage on soil acidity, nutrient redistribution, wind erosion and perennial weeds will be determined.

Project Narrative
Objectives: Declining water levels of the Ogallala Aquifer has resulted in limited groundwater supplies for irrigated crop production in the CGP region. The problem is exacerbated by high level of climate variability with reoccurring periods of severe droughts in most parts of the region. Reduction in precipitation amounts and continual depletion of the saturation thickness of the aquifer will lead to an expansion in dryland acreage across the region as producers revert to dryland farming. This provides the impetus to develop innovative technologies and management practices that will enhance productivity and profitability of dryland crop production while protecting soil, water, and air resources in the CGP. This project addresses the OAP sub-objective # 2 "*develop and evaluate management strategies and technologies that would increase the productivity and profitability of dryland cropping systems*." Research objectives are to determine the impacts of occasional tillage in long-term NT systems on 1) crop yields and soil water availability, 2) the effectiveness of occasional tillage to redistribute soil nutrients, soil acidity and control perennial grass and glyphosate resistant weeds, and 3) determine soil quality and CO_2 emissions following tillage of an otherwise long-term NT soil.
Rational/Literature Review
Irrigated agriculture in the CGP is heavily dependent on water withdrawals from the Ogallala Aquifer. However, with depletion of the saturated thickness of the Ogallala and higher pumping costs, producers may tend to return irrigated acres to dryland production**.** This scenario provides the impetus to develop and evaluate crop production strategies and technologies that will

enhance crop yields and profitability of dryland cereal-based crop production systems in the region.

Winter wheat-fallow has been the traditional dryland cropping system in the Great Plains including the CGP due to water limitation. The use of conventional tillage (CT) operations for weed control during the fallow period has resulted in insufficient crop residue return to the soil, depletion of soil organic matter, declining soil fertility, soil erosion and inefficient water storage. In recent times, the adoption of NT practices during fallow by many producers in the CGP had increased the quantity of residues retained on the soil surface. The benefits of NT include reduction in soil erosion, increased soil organic matter accumulation, improved soil structure and increased soil water storage. The increased moisture storage due to NT adoptions had allowed crop intensification in dryland cropping systems in the CGP from winter wheat-fallow to winter wheat-summer crop (i.e. grain sorghum, sunflower, or corn)-fallow.

Despite the benefits, stratification of soil nutrients, organic matter, and pH tend to develop near the soil surface in long-term continuous NT systems (Baan et al., 2009; Obour et al., 2014). This problem can reduce nutrient availability and uptake by crops and increase the chances of nitrogen and phosphorus losses in surface runoff. In addition, the lack of effective herbicides for perennial grass weeds such as three-awn grass (*Aristida purpurea* Nutt.) and tumble windmill grass (*Chloris verticillata* Nutt.) control and the emergence of glyphosate resistance weeds such as kochia and palmar amaranth pose challenges in NT crop production. To date, 14 different herbicide resistant weeds have been identified in Kansas (http://weedscience.org/details/usstate.aspx?StateAbbr=KS).

In a long-term tillage and N fertility study, Obour et al. (2015) reported that poor control of invasive grass species three-awn and tumble windmill grass in NT caused reduced winter wheat and grain sorghum yields compared to CT and RT systems. There is evidence that some producers are reverting to tillage as a cost effective means of controlling glyphosate resistant weed populations.

Occasional tillage of NT cropping systems may be necessary to alleviate herbicide resistant weed issues, redistribute soil nutrients and soil acidification developed because of continuous NT. Baan et al. (2009) showed that imposing single tillage operation on long-term NT soils had no significant effects on spring wheat yields and soil properties. Similarly, winter wheat grain yield and soil aggregate stability were not affected by one-time tillage of NT soils in eastern Nebraska (Quincke et al., 2007). However, others like Grandy et al. (2006) suggested cultivating NT systems can decrease soil aggregation and increase soil C and N losses so rapidly that all the gains made in soil restoration through NT can be undone within weeks to months after tillage. Opportunity though exist for using strategic tillage operations to correct some of the problems cause by NT without much impact on soil quality. For example, occasional tillage with moldboard plow in a RT or NT dryland cropping system controlled winter annual grass weeds and retained many of the soil quality benefits of NT (Kettler et al., 2000).

Few field studies have investigated the effects of occasional tillage on soils that have been in continuous NT (> 40-yr) in dryland conditions in the CGP. This proposed project will provide the requisite knowledge to improve our understanding of how one-time strategic tillage on long-term NT soils will affect perennial weeds, crop yields, nutrient stratification and soil quality in dryland cereal-based crop production systems in the central Great Plains.

Research Procedures: The study will be conducted using long-term and recently established tillage and crop rotation experimental plots at Kansas State University Agricultural Research Centers in Garden City, Hays and Tribune. The experiment in Hays will use long-term tillage (RT and NT) and crop rotation plots established in the summer of 1976. These long-term plots will be modified into three tillage treatments (RT, continuous NT, and one-tillage of NT) by splitting the long-tern NT plots to two equal plots of 20 ft. wide by 80 ft. long. One-half will be in continuous NT and the other half will be tilled one-time prior to winter wheat or grain sorghum planting. The experiment will be a split-plot set in a randomized complete block design with three replications. Main plots will be tillage treatments and sub-plots consists of five crop rotations: continuous winter wheat (WW), wheat-fallow (WF), wheat-sorghum-fallow (WSF), continuous sorghum (SS), and sorghum-fallow (SF), with every phase of each cropping system present in each replication for each year. The study in Garden City and Tribune will use existing NT and occasional tilled winter wheat-grain sorghum-fallow rotation plots. There will be five treatments in a randomized complete block design with four replications. Tillage treatments are 1) continuous NT; 2) light tillage every 3 years prior to wheat planting (Jun-Jul); 3) light tillage every 3 years after wheat harvest; 4) light tillage every 6 years prior to wheat planting (Jun-Jul); and 5) light tillage every 6 years after wheat harvest. All tillage operations will be done with a residue saving implement like a cultivator with sweeps.

Evaluation of Crop yields and Weeds: Grain yields will be determined by harvesting a 3.4 m x 20 m area from the center of each plot using a small plot combine. Grass and broadleaf weed plant density in each plot will be measured in the following year spring after tillage operation. Weed counts will be done by placing a 1-m^2 quadrat randomly in two locations of each plot and the number of individual plants inside the quadrat recorded. The average of the two counts will be computed to represent weed density within each plot.

Soil water measurements: Soil water availability at winter wheat planting, winter wheat harvest, sorghum planting, and sorghum harvest will be determined gravimetrically to 1.8 m in 0.3 m depth increments in all plots. Two soil cores will be taken from each plot and data averaged for a single soil water content measurement. Soil cores will be weighed wet, then placed in an oven at 105°C for at least 48 hours, and then weighed dry on consecutive days until a constant weight. Data generated will be used to assess water use and storage for each tillage and crop rotation system.

Soil Quality Measurements: Soil samples will be taken from 0 to 5, 5 to 10, 10 to 15, and 15 to 30 cm soil depths at the beginning of the study (baseline soil data) and at 12 and 24-mo after tillage operations. These samples will be analyzed for changes in soil quality parameters including bulk density, aggregate size distribution, wind erosion fraction, pH, SOC, N, P and K distribution. Briefly, bulk density will be determined by core method, dry aggregate size distribution and wind-erodible fraction by the rotary sieve method (Chepil, 1962), total N and SOC by dry combustion using Leco C/N analyzer after acid treatment. The NH_4-N and NO_3-N concentrations in samples will be determined on Seal AQ2 discrete analyzer after extracting the soil with 2 M KCl, and soil P and K by Mehlich-3 extraction method (Mehlich, 1984).

Measuring Tillage-Induced Carbon Dioxide Fluxes (only at Hays site): Responses of CO_2 fluxes to long-term (> 40-yr) NT and tillage will be monitored every 14-d using LI-8100 Automated Soil CO_2 Flux System (LI-COR, Lincoln, NE). Soil water content and temperature within 15-cm depth will also be determined simultaneously when gas sampling is made. These flux measurements will be used to quantify the impact of one-time tillage on CO_2 emissions from NT systems. In addition, the flux data will be correlated to environmental variables, such as precipitation, air temperature, soil temperature and water content.

Expected outcomes: Emerging challenges in continuous NT systems requires developing flexible management strategies that will minimize the impacts of herbicide resistant weeds and nutrient stratification on soil and crop productivity. As an outcome of the proposed project, we anticipate a significant increase in grower knowledge and understanding of occasional tillage as a management option to alleviate grass weeds and redistribute soil nutrients in dryland NT cropping systems. The findings of the study will provide the needed information on whether soil quality benefits accrued with long-term NT are negatively impacted by single tillage operation of continuous NT soil under semi-arid conditions. As an output, information generated from the study will be developed into a production guide on how to manage nutrient stratification and weed issues in continuous NT systems. Two to three peer-reviewed journal articles and extension publications will be other outputs of the project.

Technology Transfer: Study results will be presented to producers and agricultural professionals through field tours and field days, producer meetings, and scientific meetings. Publication of results in extension bulletins, news releases, publication in referred journals and production of short YouTube videos are other means the results of the project will be disseminated.

Economic Assessment Plan: Economic analysis will be done by comparing input cost and estimated net income generated from each tillage management option based on a partial budget approach. Total input usage will be recorded for each treatment in order to accurately calculate cost differences across treatments. Likewise, total production will be measured for each treatment in order to determine if there are any economic benefits to occasional tillage of an otherwise long-term NT cereal-based crop production system.

Pertinent Publications:

Obour, A.K., P. W. Stahlman and C. A. Thompson. 2015. Wheat and grain sorghum yields as influenced by long-term tillage and nitrogen fertilizer application. Int. J. Soil and Plant Sci. 7:19-28.

Obour, A.K., and P.W. Stahlman. 2014. Long-term tillage and nitrogen fertilizer application effects on crop yields and precipitation use efficiency in a wheat sorghum cropping system. *In* Proceedings Great Plains Soil Fertility Conference. 2014. Vol. 15. Denver, CO. pp.6-11.

Obour, A.K., E. Obeng, and P.W. Stahlman. 2014. Soil acidity and nutrient stratification as affected by long-term tillage and nitrogen fertilization. *ASA-CSSA-SSSA Annual Meeting*, Long Beach, CA, November 2-5, 2014.

Schlegel, A.J., and J.L. Havlin. 1997. Green fallow for the central Great Plains. Agron J. 89:762-767.

References

Baan, C.D., M.C.J.Grevers, and J.J. Schoenau. 2009. Effects of a single cycle of tillage on long-term no-till prairie soils. Can. J. Soil Sci. 89:521-530.

Chepil, W.S. 1962. A compact rotary sieve and the importance of dry sieving in physical soil analysis. Soil Sci. Soc. Am. Proc. 26:4-6.

Grandy, A.S., G. P. Robertson, and K. D. Thelen. 2006. Do productivity and environmental trade-offs justify periodically cultivating no-till cropping systems? Agron. J. 98:1377-1383 .

Kettler, T.A., D.J. Lyon, J.W. Doran, W.L. Powers, and W.W. Stroup. 2000. Soil quality assessment after weed-control tillage in a no-till wheat-fallow cropping system. Soil Sci. Soc. Am. J. 64:339-346.

Mehlich, A. 1984. Mehlich 3 soil test extractant: A modification of the Mehlich 2 extractant. Commun. Soil Sci. Plant Anal. 15:1409-1416.

Obour, A.K., P. W. Stahlman and C. A. Thompson. 2015. Wheat and grain sorghum yields as influenced by long-term tillage and nitrogen fertilizer application. Int. J. Soil and Plant Sci. 7:19-28.

Obour, A.K., E. Obeng, and P.W. Stahlman. 2014. Soil acidity and nutrient stratification as affected by long-term tillage and nitrogen fertilization. *ASA-CSSA-SSSA Annual Meeting*, Long Beach, CA, November 2-5, 2014.

Quincke, J.A., C. S. Wortmann, M. Mamo, T. Franti, R. A. Drijber, and J. P. Garcia. 2007. One-time tillage of no-till systems: soil physical properties, phosphorus runoff, and crop yield. Agron. J. 99:1104-1110.